University of Michigan at Ann Arbor CIREN Center

CIREN Program Report

Michigan, 2001

The University of Michigan CIREN Center is situated within one of the leading biomedical research centers in the world, the University of Michigan Medical Campus Health System. The Ann Arbor-based Center has also benefited from the expertise in injury biomechanics and crash investigation within the Biosciences Division of the University of Michigan Transportation Research Institute (UMTRI), where research in injury causation and motor-vehicle crash investigations has been conducted for more than thirty years. It is also uniquely situated in close proximity to the automobile industry and its major seat and restraint-system suppliers, so that the safety engineers who design today's occupant protection systems can participate first hand in the review and analysis of crashes selected for in-depth investigations. These two features have enabled the UofM CIREN center to perform high-quality crash investigations in a timely manner, and to analyze crash and injury data with a unique and comprehensive understanding of the bio-mechanics of injury and vehicle and restraint design features.

University of Michigan Survival Flight helicopters evacuating injured patients from a crash scene.

The Crash Injury Research and Engineering Network (CIREN) project was a major impetus for the formation of the University of Michigan Program for Injury Research and Education (UMPIRE). UMPIRE is a multi-disciplinary program dedicated to studying the effects of injury so that better means of prevention can be devised. Prior to CIREN's inception, multiple researchers throughout the University of Michigan had extensive investigational activities touching on specific aspects of motor vehicle safety. However, these researchers generally focused their activities within their individual scientific disciplines of engineering, public health, or medicine. The newly created CIREN project required a multidisciplinary approach that combined expertise from all of these fields as well as others. It also required that academic researchers work with law enforcement, emergency medicine providers, safety advocates, and government regulators

University of Michigan Transportation Research Institute

University of Michigan Health System

in addition to researchers, designers, and engineers from industry. UMPIRE was created to bring these groups together, as well as other parties with a common interest in motor vehicle safety. By helping to bridge these groups, the University of Michigan team could better conduct its CIREN research activities while at the same time enhancing collaborations outside of CIREN for the purpose of improving public safety.

Discussion of vehicle kinematics during a case review

Today, the University of Michigan Program for Injury Research and Education is comprised of a diverse group of individuals from many backgrounds and fields of expertise. The core team includes:

Stewart Wang, MD, PhD,
Director, UMPIRE
Associate Professor of Surgery,
Director of Research – Trauma Burn Center,
Principal Investigator of CIREN, Michigan.

Carla Kohoyda-Inglis, Database Coordinator

Terri Kennedy, RN, Injury Research Coordinator

June Lee, MPH, Research Associate

Sandy Lemkin, Project Coordinator

Alice Yan, MS, Database Analyst & Statistician

Elizabeth Link, Administrative Assistant

Pam Snyder, Surgical Technician

Martin Lambrecht, Johnson Controls/UMPIRE Fellow

Stephen Fuks, Visteon/UMPIRE Fellow

UMPIRE has been assisted from the beginning by a team from the University of Michigan Transportation Research Institute (UMTRI). The Biosciences Division at UMTRI has been conducting crash investigations and research for more than 35 years. Our UMTRI team includes:

Lawrence Schneider, MS, PhD,
Director of Biosciences Division,
Co-Investigator of CIREN

Joel MacWilliams, Senior Crash Investigator

Dale Halloway, Crash Investigator

Tim Compton, Crash Investigator

Jamie Moore, Crash Investigator

Chris VanEe, PhD, Assistant Research Scientist

John Melvin, UMTRI Consultant

UMPIRE draws upon the extensive knowledge and experience of the University of Michigan Medical School Faculty. Regular participants in UMPIRE activities include:

James Goulet, MD, Orthopedic Surgery,
Director of Orthopedic Trauma

Hugh Garton, MD, MHsc, Pediatric Neurosurgery

Daniel Remick, Jr., MD, Pathology,
Director of Autopsy Service

Curtis Hayes, MD, Radiology,
Director of Bone Imaging

Ella Kazerooni, MD, Radiology,
Director of Chest Imaging

David Fessell, MD, Radiology

David Marcantonio, MD, Radiology

Smita Patel, MD, MRCp, Radiology

Wendy Wahl, MD, Trauma Surgery

Mary-Margaret Brandt, MD, Trauma Surgery

Glen Franklin, MS, MD, Trauma Surgery

CIREN case reviews address the obvious void between testing or validation with the ATD's (with specified sizes, weights and vehicle positions) and the biomechanics using cadavers (tend to be elderly, female, etc). The driver/passengers within the vehicle interior are not rigid and motionless but in constant fluid motion. The ATD's and biomechanical testing can not possibly address every possible scenario, however, the CIREN cases fill some of the gaps and can provide direction.

—an automotive engineer

UMPIRE also draws regularly on the expertise of professionals from local government:

Bader Cassin, MD, Chief Medical Examiner for Washtenaw and Livingston Counties

Carl Hein, EMT, Director, Education Division,
Ann Arbor Fire Department

Mark Luick, Ann Arbor Fire Department

RESEARCH

As the Michigan CIREN Center, one of our primary aims is to collect data for the CIREN National Database. We recruit an average of fifty cases per year to analyze and enter into the database. These cases are the backbone of the crash injury research at UMPIRE. After extensive preparatory investigations by individual team members, we gather the entire team together once a month to take on the work of forensic investigators and determine the mechanisms by which injuries to study subjects were caused during their motor vehicle crash. Given our location and close proximity to large concentrations of automotive engineering and testing expertise, our center is unique in its ability to enlist the assistance of engineers who have first-hand knowledge of the vehicles involved in our analysis of the vehicle's interaction with the occupant during the crash. Although it is not possible to determine with absolute certainty the exact way a specific injury was caused, great effort is spent to determine the several most likely scenarios based on all the evidence gathered as well as the combined analytical expertise of the medical, biomechanical, crash investigation, and vehicle engineering expertise present. Once the causation mechanism for an injury is determined, that information is entered into the CIREN database so that it is accessible to automotive engineers.

The case reviews keep me from getting complacent about safety. When dealing with specifications and standardized crash tests, you get used to running an experiment in which many factors are controlled (impact speed, PDOF, seat position, occupant stature, etc.). The case reviews show that nothing is fixed or set in real-life crashes, and they force automotive engineers to go look at what the variables were and how they influenced the crash outcome. In a standardized crash test, there are certain things to look for; after my first case review, I realized that there are other things I should also consider; and each subsequent CIREN case has only added to this understanding.

—an automotive engineer

From the large body of data that we have gathered for the CIREN project, several areas have been of particular interest for our group:

Biomechanics of Hip and Thoracic Injuries

One of the primary differences between a CIREN crash investigation and investigations conducted by other programs such as the National Automobile Sample Systems (NASS), is that each CIREN case is based on a "case occupant" who has been admitted to a level-1 trauma center due to injuries, or suspected injuries, sustained in the crash. Because of this, accurate and detailed injury data, including medical records and images, are available for the case occupant. These detailed injury data are used, along with detailed crash and vehicle-damage data and direct input from treating and diagnosing physicians, in determining occupant kinematics and injury causation. Thus, CIREN investigations include information about the specific types and locations of skeletal and soft-tissue injuries, as well as information about pre-existing medical conditions that may have contributed to those injuries. While such information is not necessary for many types of analyses, these detailed injury data significantly increase the utility of real-world crash-investigation data to biomechanical researchers. For example, specific images and information of a fracture to the mid-shaft of a long bone can be used to determine if the bone fractured in bending, in axial compression, in twisting, or in shear, and can thus provide clues to the manner in which the limb was loaded in a crash. Such detailed injury data from the UofM CIREN cases are being used in two areas of biomechanical injury research at UMTRI – 1) hip fractures and dislocations, and 2) thoracic injuries.

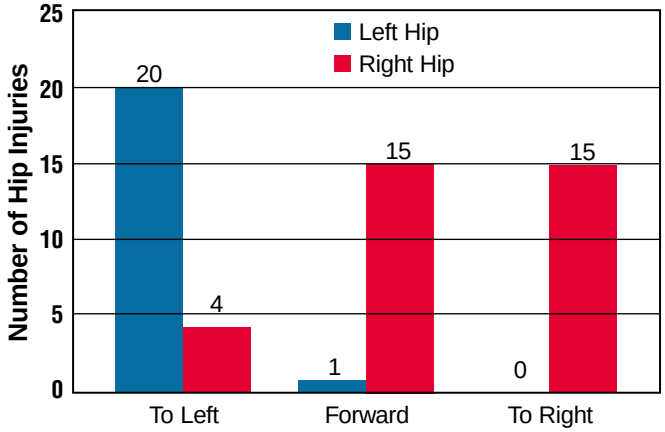
By being able to cite the high incidence of leg injuries, there is evidence to go to the product design teams and work on designing a better restraint system to help prevent these types of injuries.

–an automotive engineer

With the success of increased belt use rates and airbags in frontal crashes, the UofM CIREN center admits many victims of severe frontal crashes who have relatively minor injuries to the head, face, neck chest, and abdomen, but who have sustained life-time disabling injuries to the lower extremities. Among these lower-extremity injuries, fractures and dislocations of the hip joint are over represented in the UofM CIREN cases. These injuries are occurring to both belt-restrained and unbelted front-seat occupants of late model vehicles involved in frontal crashes that are similar in severity to those conducted for federal safety testing. This has led to the initiation of a new biomechanical effort at UMTRI to investigate human tolerance to, and causal factors involved in, hip injuries due to impact loading through the knees. Analysis of the crash conditions under which these hip injuries occur in UofM CIREN cases has led to the observation shown in the chart below that the injured hip is almost always on the side of the body to which the occupant moved during the frontal crash due to the location and direction of the impact (i.e., due to the principal direction of force for the case vehicle). This suggests two possible factors involved hip injuries that are being explored further in biomechanical testing – 1) that adduction of the hip joint during knee loading reduces the

area of contact of the femoral head on the posterior wall of the acetabulum, thereby reducing the tolerance to fracture and dislocation, and/or 2) that the knee/thigh/hip complex on the side to which the body moves is loaded more than on the uninjured side. To study these and other factors that may contribute to the increased likelihood of hip injury in frontal crashes, controlled laboratory tests with human surrogates are being conducted at UMTRI. Detailed data on hip and pelvic fractures in frontal crashes from the UofM CIREN database are being compared to injuries obtained in these laboratory tests, and provide the basis for validating the laboratory test conditions.

Direction of Occupant Movement based on Principal Direction of Force (PDOF)



In a similar manner, UofM CIREN researchers are using the detailed injury data from the CIREN cases to examine injury patterns of skeletal and visceral thoracic injuries. In particular, CIREN researchers are documenting the specific circumferential and vertical locations of rib fractures from frontal and lateral loading and from different types of restraints and objects (belts, airbags, door interiors, etc.). The results should help interpret and validate thoracic injuries obtained from laboratory testing using human surrogates, and should provide useful information for determining the way in which the torso was loaded in real-world crash investigations. Preliminary findings suggest that the patterns of skeletal injuries in living persons can be quite different from those obtained in laboratory testing, and that, unlike testing with human surrogates, are usually accompanied by significant visceral injuries. The results also suggest that the locations of rib fractures can vary significantly for different occupants exposed to similar loading conditions.

Finally, detailed information on the locations and nature of aortic ruptures to occupants of frontal and near-side impacts in CIREN are being compiled from CT images. The results are being used to validate research methods of experimental testing and computer modeling aimed at determining the specific mechanisms of these vascular injuries that are almost always fatal.

Elderly

There are more than 25 million people age 70 years and older in the United States. In 2000, this age group made up 9.2 percent of the total U.S. resident population, compared with 8.5 percent in 1990. From 1990 to 2000, this older segment of the population grew nearly twice as fast as the total population.

There were 18.5 million older licensed drivers in 1999 (2000 data not available)—a 39 percent increase from the number in 1989. In contrast, the total number of licensed drivers increased by only 13 percent from 1989 to 1999. Older drivers made up 10 percent of all licensed drivers in 1999, compared to 8 percent in 1989.

In 2000, 181,000 older drivers were injured in traffic crashes, accounting for 6 percent of all the people injured in traffic crashes during the year. These older drivers made up 13 percent of all traffic fatalities, 12 percent of all vehicle occupant fatalities, and 17 percent of all pedestrian fatalities.

Better health and longer life expectancy will mean a greater mobility for older drivers. All of these factors will increase

Changing U.S. Demographics by Age Group

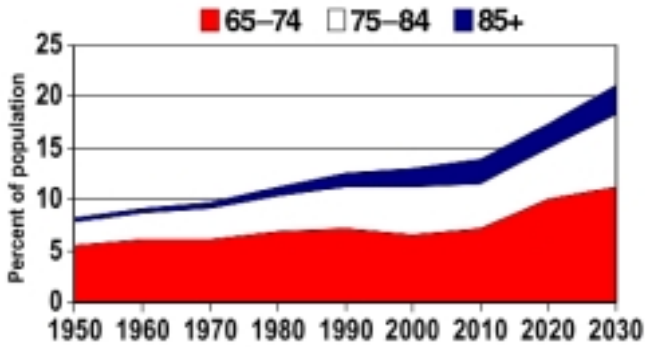
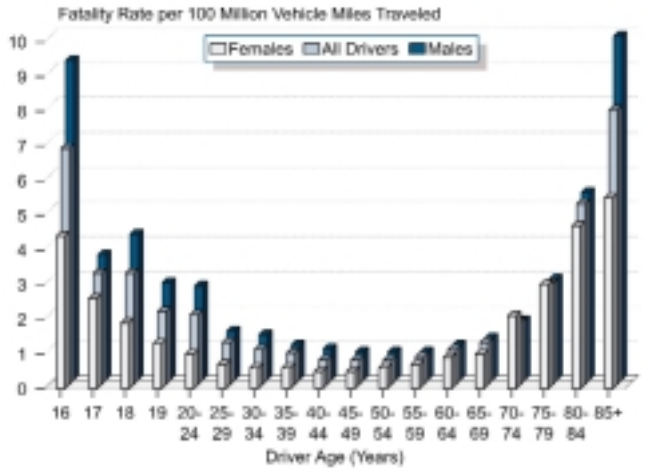


Chart clearly shows trend toward an older population

the traffic exposure of older drivers in terms of the number of miles driven per year.

Detailed medical analysis of real-life crash cases at our center shows that while total injury rates are higher in elderly motor vehicle crash (MVC) occupants than younger MVC occupants, there are significant differences in their respective injury patterns, particularly in the torso. In our studies examining the outcomes of real-life MVCs, we have found that elderly occupants are much more susceptible to injuries to the thoracic region where we have noted increases in both the incidence and severity of injuries. In contrast, we have noted decreases in both the incidence and severity of abdominal injuries with aging. We have also noted a decrease in the incidence of brain and lower extremity injury by age, but an increase in severity. Efforts are currently underway at UMPIRE to determine in greater detail how and why injury patterns change with the aging of the

Driver Fatality Rates by Age and Gender, 1996



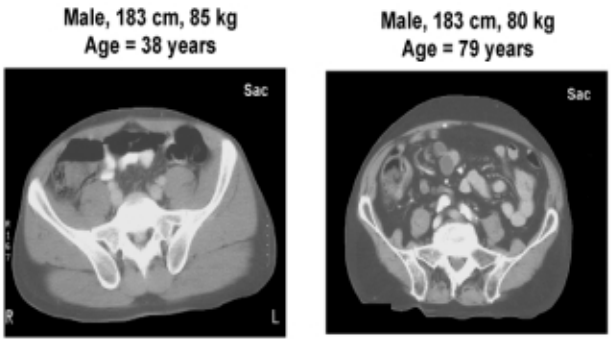
population. The diverging vulnerability of different body regions to MVC injury with aging suggests that the ability of different body regions to tolerate blunt trauma may change differentially with aging.

Body Composition – Effect on Injury Tolerance

For the past several decades, vehicle safety systems have been developed based on various criteria measured by crash dummies that are designed to represent an idealized occupant of fiftieth percentile height and fiftieth percentile weight with the tissue properties of a 45-year-old. There has been scant attention paid to age effect or the effects of differences in body composition. In the construction of a vehicle, the frame or chassis is necessarily the strongest and stiffest part of the vehicle. In this way, the frame plays a role similar to the skeleton of the body, which forms a scaffold for the soft tissues and viscera of the body. Other structures in a vehicle are made of sheet metal, making them less stiff and more prone to deformation or damage when subjected to crash forces.

We cannot use live subjects to experimentally determine the effect of age and body composition differences on injury tolerance in crashes. However, with tremendous improvements in medical imaging technology over the past decade, we can now capture body composition data in precise anatomic detail. Computed tomography (CT) scans are the evaluative method of choice for blunt polytrauma. The cutting edge CT scans available at the University of Michigan Medical Center capture precise details about the injuries as well as the patient's baseline body composition. Studies are currently underway to determine how alterations in body composition (bone density, fat, and muscle distribution) affect injury tolerance. We anticipate that these studies will provide valuable information that can be used to tune vehicle safety systems to each individual occupant so that crash safety can be maximized.

CT Scan Images



"Computed tomography scan of the pelvic region demonstrates that different components of the body (BONE - white, MUSCLE – gray, FAT – dark gray) change with increasing age. Muscle mass, bone mass, and bone density decrease with aging. In contrast, fat mass increases.

Case reviews are valuable in that the open discussions, the various crash vehicles and conditions as well as the medical input will undoubtedly lead to safer designs. Typically, engineers look at data from test dummies and simulations. To be able to discuss and analyze what are real world situations with colleagues from competitor companies has heretofore not been an option. I look forward to continued participation.

—an automotive engineer

EDUCATION

As our name states, the second major aim of UMPIRE is education. The first aim, research, is necessary to better understand how and why injuries take place. However, improved knowledge gained from research is useless unless it is applied practically. Education is the essential counterpart to research that transmits knowledge to those who can apply it usefully. Insights from our multidisciplinary research activities are actively transmitted back to UMPIRE participants and their sponsoring organizations so that improvements in vehicle safety and trauma care can be better effected. At the same time, we have dedicated great effort to educating the general public. Education is the first step to prevention. UMPIRE team members have taught elementary school classes about the importance of using booster seats and seat belts properly. We are currently in the process of developing a curriculum that will be taken to elementary schools throughout the region with the assistance of volunteers from the University of Michigan and financial support from corporate sponsors.

UMPIRE Researchers speak to a local multi-age classroom

The data from CIREN provides the most current information available regarding injuries caused by motor vehicle crashes. Changes are constantly taking place within the population as well as the vehicle fleet. As a result, injury patterns change as well. Findings and insights from CIREN can help emergency medical service providers and physicians more rapidly diagnose and treat life-threatening injuries. We have relayed our CIREN findings on a constant basis to local, regional, and national medical groups. Within the medical center, UMPIRE team members have given numerous lectures to nurses, medical students, and surgical residents. In addition, team members have highlighted case presentations at the weekly trauma conference at the University of Michigan as well as other area hospitals. Insights and case presentations from CIREN have been made at local and regional EMS and Emergency Medicine conferences as well as trauma conferences for physicians and allied health personnel. Multiple presentations have been made at national public health and surgical meetings. CIREN findings from Michigan have also been presented in England and Sweden.

We feel it is important that the people who directly influence the development of vehicles be engaged as much as possible. From the beginning, engineers from GM (our initial sponsor) were invited to participate in our monthly case review meetings. Subsequently, we opened our meetings to other auto manufacturers as well as their suppliers. Since that time, we have had safety engineers and other representatives from the following companies attend: Aeroteck Scientific Staffing, Autoliv, Breed Technologies, Daimler-Chrysler, Delphi Automotive, Dow Automotive, Ford Motor Company, Johnson Controls, Polymer Solutions, Inc. (GE Plastics), Nissan, Toyota, TRW, and Visteon. During these monthly case review meetings, we place great emphasis on cross-education of the many scientific disciplines present. Time is set aside to teach medical

CIREN Public Meeting in Ann Arbor, September 2001

concepts to the engineers and vice versa. Visiting professors, alternating between medical and engineering specialties, are invited to present teaching seminars as part of our case review meetings. The interest and support from the automotive engineering and medical communities has been overwhelming. Attendance at our monthly case reviews exceeds the room capacity of forty and is standing room only.

I believe the biggest impact came from the UMPIRE / CIREN Team presentation last summer. Most of our engineers never deal with vehicle safety / crash testing themselves, they only see the specifications. They walked away more aware that "this is what an accident really looks like" and I think they were able to associate pictures and outcomes with the numbers and formulas.

–an automotive engineer

As important as the case reviews are, we are limited by space and time constraints. To this end, we have traveled to several companies in an effort to bring the case reviews and their resultant insights to a larger number of automotive engineers. The UMPIRE team has given presentations at GM, Ford, Chrysler, Johnson Controls, and Visteon. Although it is not a true case review with the exchange of ideas that is usually present, it gives a larger audience an idea of what comes out of case review and the importance of having many people from different disciplines participate.

UMPIRE Injury Research Fellowship

Lead-time is needed to design, test, and manufacture safety systems and vehicles. Any delay in getting data and insights back to the engineers degrades the usefulness and relevance of the information. Time is, therefore, of the essence in analyzing and sharing data. The mass of data collected by CIREN needs to be sorted and organized in a

Multidisciplinary group at a case review

way that makes it useful to the automotive engineers who will be using this information to improve vehicle design. The UMPIRE team takes special care to avoid introducing bias during the collection process or reducing the granularity of the data. We feel that the engineering end users are necessary participants in the process. Medical and engineering specialists both have much to learn from the other with regards to injury causation and prevention in motor vehicles. Both sides have pieces of a puzzle that they have been trying to put together without the other. Without working together, the quality of the data and of its analysis will not improve. We determined that the best way to have medical and engineering specialists learn from each other while working together was to put them side-by-side in a combined fellowship program.

UMPIRE Fellows and staff get hands-on occupant extrication training

Since UMPIRE initiated the fellowship program in April 2001, our inaugural fellows have had the opportunity to go out with our crash investigators to examine the crash scene and vehicle prior to reconstructing the events of the collision. In conjunction with this, they have had the chance to examine the occupant's medical records and studies. By observing the gathering of case data from start to finish, they have a better appreciation of the strengths and limitations of data in the CIREN database. The Fellows have attended surgical operations and autopsies as well as a series of lectures given by our affiliated medical and engineering staff. They have been taught the principles of rescuing entrapped occupants by firemen and had the opportunity to try it first-hand. A fellowship is an optimal way for someone already trained in a field to gain the additional expertise necessary to tackle a specialized problem. Fellows differ from students in that they already have expertise in their general field. Fellows need real-life problems to work on rather than hypothetical exercises; they need hands-on training rather than classroom learning. Any improvements we make in the expertise of our engineering and medical fellows will improve the quality of our mutual research and make advances in automotive safety design and medical treatment possible. This improved expertise will enable the engineering fellows to better support the mission of their companies and enable medical fellows to better support the patient care mission of their institution. At the same time, the enhanced mutual understanding fostered by this close collaboration and training will improve the quality of data coming from our center and all CIREN centers.

Information from the case reviews serves as another data point to assist in decision making when trying to design and optimize, as much as possible, a restraint system.

–an automotive engineer

SUMMARY

The work coming from the CIREN centers around the country is valuable. At UMPIRE, we feel a strong sense of urgency to disseminate this information to the people who can effect the most change in automotive design and safety. We have committed ourselves to providing a forum for individuals from many disciplines to exchange ideas and opinions. At the same time, we are actively educating everyone from EMTs to medical personnel to automotive engineers to school age children about safety and prevention. It is, in the end, about people.

Selected Extramural Presentations

"Crash Injury Patterns in Elderly Motor Vehicle Occupants." Trauma Conference. University of California, San Diego. February 1999.

"Prevention of Injury Through Automotive Engineering." Trauma Care 1999. A Focused Review. Ypsilanti, Michigan. February 1999.

"Injury Outcomes in Crashes Involving Chrysler Vehicles." Auburn Hills, Michigan. February 1999.

"Crash Injury." EMS Expo 1999. Grand Rapids, Michigan. April 1999.

"Motor Vehicle Crash Injury." Academy of Surgery of Detroit. Detroit, Michigan. April 1999.

"Mechanisms and Outcomes of Injuries to the Knee-Femur-Hip Complex." National Highway Traffic Safety Administration. Washington, DC. May 1999.

"Injury Patterns and Causation Mechanisms." Regional Extrication Learning Symposium and Team Challenge. Farmington Hills, Michigan. June 1999.

"Injury Patterns and Mechanisms in Motor Vehicle Crashes." Surgery Grand Rounds, University of Pittsburgh. Pittsburgh, Pennsylvania. June 1999.

"An Aging Population: Fragile * Handle with Care." CIREN public meeting. Ann Arbor, Michigan. September 1999.

"Patterns and Mechanisms of Injury in Motor Vehicle Crashes." William Beaumont Medical Center. Royal Oak, Michigan. October 1999.

"Maxillofacial Injuries in North American Vehicle Crashes." British Trauma Society Annual Meeting. October 1999.

"Injury Patterns and Outcomes in Elderly Motor Vehicle Occupants." Third CIREN Annual Conference. San Diego, California. October 1999.

Child safety seminar. "Medical considerations for injury prevention among small children involved in motor vehicle crashes." Children's Museum of Los Angeles. Los Angeles, California. January 2000.

Child safety seminar. "Medical considerations for injury prevention among small children involved in motor vehicle crashes." Children's Museum of Chicago. Chicago, Illinois. February 2000.

"Mechanisms of Blunt Trauma in Motor Vehicle Crashes. Trauma 2000 Symposium." St. Joseph's Mercy Medical Center. Ann Arbor, Michigan. February 2000.

"Current Progress in Trauma Burn Research." Ford Motor Corporation Physicians Worldwide Visit to Ann Arbor. Ann Arbor, Michigan. March 2000.

Child safety seminar. "Medical considerations for injury prevention among small children involved in motor vehicle crashes." Children's Museum of Manhattan. New York, New York. April 2000.

"Emerging Patterns in Acetabular Fractures Following Motor Vehicle Crashes." CIREN Quarterly Conference. Washington, DC. May 2000.

"The Small Child in a Frontal Car Crash: Medical Considerations." Volvo Safety Center. Gothenburg, Sweden. July 2000.

"NASS Based Investigation of Obesity and Injury Severity in Motor Vehicle Crashes." American Pubic Health Conference, Injury Control and Emergency Health Services Poster Session. Boston, Massachusetts. November 2000.

"Torso Injury Patterns in Motor Vehicle Crashes." Trauma 2000. Annual Congress of the Scandinavian Trauma Society. Gothenburg, Sweden. November 2000.

"Emerging Patterns of Thoracic Injuries in Motor Vehicle Crashes." CIREN Quarterly Conference. Washington, DC. December 2000.

"Human Injury Data for Safer Vehicle Design: Lessons from Real Life an the Laboratory." Global Automotive Safety Conference. Society of Plastic Engineers. Southfield, Michigan. February 2001.

"Occupant Injury Patterns and Offset Frontal Collisions." CIREN Quarterly Conference. Washington, DC. March 2001

"Pediatric Injuries Associated with Specific Types of Restraint Misuse." 5th Annual International Child Passenger Safety Technical Conference Technical Issues, Standards and Regulation Workshop. Indianapolis, Indiana. June 2001.

"Patterns of Skeletal and Visceral Thoracic Injuries in Frontal and Near-Side Impacts." Moses Gunn Surgical Research Conference, Ann Arbor. June 2001

"Crash Injury Data for Automotive Engineers: Lessons from Real Life." CIREN quarterly conference. Washington DC. June 2001

"Human Injury Trends Driving the Next Generation of In-Vehicle Electronics." Intelligent Vehicles Conference. Chicago. July 2001

"Crash Injury Research. Emergency Medicine Grand Rounds." Ann Arbor, MI. August 2001.

"Crash Injuries and SUVs: Michigan Case Presentations." CIREN quarterly conference. Ann Arbor. September 2001.

"Detailed Injury Analysis of Knee, Thigh and Hip injuries in Frontal Motor Vehicle Crashes." American Public Health Conference, Injury Control and Emergency Health Services Poster Session, Atlanta. October 2001.

Publications:

Wang SC, Schneider L. "An Aging Population: Fragile – Handle with Care." *Proceedings of the National Highway Traffic Safety Administration*, 1999.

Wang SC. Invited Commentary: "Today's CIREN: News you can use." *Annals of Emergency Medicine*. 38(2): 182-3, 2001

Patel NN, Wang SC. "Arterial dissection injury following motor vehicle collision." *J Trauma*. In Press.

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Articles Submitted for Publication

Tencer A, Kaufman R, Ryan K, Grossman D, Henley B, Mann F, Mock C, Rivara F, Wang SC, Augenstein J, Hoyt D, Eastman B. "Femur fractures in relatively low speed frontal crashes: The possible role of muscle forces." *Accident Analysis and Prevention*. Submitted.

Wang SC, Schneider LW, Alarcon WH, Knight KM, Kohoyda-Inglis CJ, Macwilliams, JB, Pucci PS, Augenstein JS, Burgess A, Cooper G, Dischinger P, Eastman AB, Grossman D, Hoyt DB, Loo G, Rivara F, Siegel JH, Elliot D, MuCullough C, Brown L. "High incidence and morbidity of rib fractures in elderly motor vehicle crash occupants." *J Trauma*. Submitted.

Patel NN, Wang SC, Marentette L. "A comprex and unusual penetrating injury of the cheek requiring skull base exploration." Submitted.

Abstracts

Alarcon WH, Klein RD, MacWilliams J, Pucci P, Taheri P, Dries D, Schneider L, Wang SC. "Comparison of Outcomes of Passenger-Sedan Occupants from Near-Side Impacts by Sport Utility Vehicles and Pickup Trucks." *Proceedings of the 58th Annual Meeting of the American Association for the Surgery of Trauma*, 1998, 180.

Wang SC, Schneider L. "An Aging Population: Fragile – Handle with Care." *Proceedings of the Crash Injury Research Engineering Network Conference*. 1998.

Brookes C, Wang SC, MacWilliams J. "Maxillofacial injuries in North American vehicle crashes." *Proceedings of the British Trauma Society Annual Meeting*, 1999.

Orzechowski KM, Lee JH, Eichelberger MR, Wang SC. "Pediatric injuries associated with specific types of restraint misuse." *Proceedings of the International Child Passenger Safety Conference*. 2001.